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## Digital Crowdsourcing in Healthcare Environment Co-design

**Lei Shi**

*lei.shi@warwick.ac.uk*

*International Digital Laboratory, WMG, University of Warwick  
Coventry, United Kingdom*

**James MacKrill**

*j.b.mackrill@warwick.ac.uk*

*International Digital Laboratory, WMG, University of Warwick  
Coventry, United Kingdom*

**Carolyn Dawson**

*c.h.dawson@warwick.ac.uk*

*International Digital Laboratory, WMG, University of Warwick  
Coventry, United Kingdom*

**Elisavet Dimitrokali**

*e.dimitrokali@warwick.ac.uk*

*International Digital Laboratory, WMG, University of Warwick  
Coventry, United Kingdom*

**Rebecca Cain**

*r.cain.1@warwick.ac.uk*

*International Digital Laboratory, WMG, University of Warwick  
Coventry, United Kingdom*

### Abstract

Improving user experiences of healthcare environments via their participation has become a central theme in healthcare studies and strategic agendas. The co-design approach is often utilized to take into account opinions from different stakeholders including hospital staff. However, there are a number of competing stimuli and demands on staff at any point in time potentially making it difficult for them to participate in the co-design processes. Digital crowdsourcing may engage staff in participating in the design and appraisal of hospital environments when they have a spare moment by collecting small amounts of relevant data. In order to explore this, we have implemented a *digital crowdsourcing co-design* prototype. As users' perceived acceptance of technologies is among the determining factors for a successful digital approach, in this paper, we report on participants' acceptance of the prototype, aiming to reflect if and to what extent they accept this prototype to aid further development.

**Keywords:** Healthcare environment, co-design, crowdsourcing, evaluation, acceptance.

### 1. Introduction

The application of co-design [19] has been adopted by a diverse range of sectors ranging from traditional product development through to application in healthcare. Central to its applications is to understand the user perspective. Improving patient and staff members experiences of healthcare environments and services via their participation has become a central theme in health research [2] and strategic agendas [36]. This has involved different stakeholder groups in discussions about personal experiences of healthcare and how environments and services might be improved, often utilizing the co-design approach. For example, The Kings Fund [37] carried out the Patient Centered Care Project to improve the experience of breast and lung cancer treatment within a UK NHS (National Health Service) hospital. The investigation used "Experience-Based Co-Design" and included interviews, ethnographic observations, and group work.

The participation of different stakeholder groups offers particular contributions to quality improvement thinking in the healthcare sector: a new lens, or frame of mind, through which to think about approaches to improving user experience of healthcare, as well as methods, technologies and tools [10]. Yet, it also raises challenges: how do stakeholders challenge and augment the “finished design” to suggest design changes; how can their subjective opinions, ideas, thoughts, needs and experience about an environment be captured and translated into a format meaningful for designers and engineers?

Crowdsourcing [16] is the process of obtaining needed ideas, solutions or content by soliciting contributions from a large group of people. It takes the crowd’s contribution as a whole, which can potentially eliminate bias and omit missing data thus reducing risks. The emergence of crowdsourcing may fundamentally change the co-design approach as designers can now play with these “new materials” and the way of obtaining them. This introduces a new context for crowdsourcing where researchers and designers may tackle the co-design challenges in the healthcare sector.

The work presented in this paper investigates the application and use of the co-design approach and crowdsourcing technology, in order to promote situated engagement of hospital staff in the appraisal and improvement of healthcare environments. This work follows a *research through design* approach [34] where speculative prototypes are developed using methods from Human-Computer Interaction (HCI) and from environment and service design, as a way of learning how to best deploy such digital co-design tools.

This paper presents a preliminary study on the implementation and evaluation of a *digital crowdsourcing co-design* prototype. Given the fact that participants’ acceptance of taking part in the co-design process using digital co-design tools can potentially influence the quality and quantity of their participation and contribution, their acceptance of the method is among the determining factors for the success [31]. Therefore, it is crucial to investigate if and to what extent they accept the proposed method. The results may in turn reveal the influence of the acceptance, thus suggesting further development and improvement of the method. This study was designed to understand the use of the method in a controlled environment. Therefore, this paper focuses exclusively on examining participants’ perceived acceptance of the implemented prototype, in the context of hospital ward simulated within a controlled environment. Acceptance was then assessed using a questionnaire survey designed based on a previous study [21] that applied the Technology Acceptance Model (TAM) [6].

## 2. Related Work

### 2.1. Co-Design

Co-design is an iterative, interactive and inclusive process where all stakeholders including researchers, designers and people formerly known as the “users” are engaged in the development of new solutions [19]. It encourages the blurring of the role between different stakeholders, focusing on the process by which design objectives are achieved. It believes that the final results will be more appropriate and acceptable to end-users by encouraging this co-creation of solutions, as the quality of design increases if the stakeholders’ interests are considered in the design process [1]. Over the past decades co-design has been widely accepted in the areas of product design, system design, service design, and human-computer interaction (HCI) [17]. A more recent study [20] theorized that this creativity-based approach requires scaffolding of the physical design space a team works in, the space constituted by participant activities, and the future solutions being developed. This normally involves methods such as workshop-based design sessions that need participants’ time commitment.

However, in the context of healthcare environment improvement where staff members have multiple demands at any point in time, there are many challenges to bring them in the co-design process using traditional workshop-based methods. Thus, the study presented in this paper aims to explore an innovative method drawing from the recent attempts to adapt the

co-design approach through situated participation [33] and using social computing techniques to engage users who may be dispersed due to work activities (e.g., [9, 32]).

## 2.2. Crowdsourcing

Crowdsourcing can be seen as a particular distributed co-creation model that provides a comfortable venue where participants are not being judged or scrutinized thus might feel more comfortable to participate. It can be very efficient and effective as participants are less conscious or aware of scrutiny towards their contribution [8]. It can be seen as a form of “open innovation”, which depends heavily on the involvement and engagement of participants [18]; it can also be seen as information probes [5] capturing small insights into the everyday concerns of participants. The offerings of crowdsourcing, its desires and aims are in a way overlapped with those of co-design, by eliciting insights from users. Therefore, linking the two approaches may provide robust, decentralized and human-scale resources to the co-design process. Thus crowdsourcing models can potentially bring in benefits to co-design, especially in the context of improving healthcare environments. However, it is difficult to prototype crowdsourcing platforms, as researchers and engineers are not able to precisely predict if and to what extent users will contribute the information required to make a platform valuable to them [35].

Whilst little research has been done on how to design and improve prototyping of crowdsourcing platforms, a great amount of studies have been conducted to investigate theories and practices capable of engaging and motivating participants’ contribution. Take the field of social computing for example, extensive work has been done to explore specific approaches to increase interaction, collaboration, and cooperation among individuals, as well as contribution to a community. These approaches include tightening social connection [27], visualizing social interaction [23], exposing individual performance and contribution [24], adopting gamification strategies [26], and applying motivational theories [25] such as social connectivism [29] and self-determination theory (SDT) [3]. These overarching studies can potentially contribute to the development of co-design crowdsourcing platforms. Therefore, the study presented in this paper takes into consideration these theories and practices when implementing and evaluating the prototype.

## 2.3. Situated Engagement

Situated engagement is the process of engaging an individual at a moment of time within a specific environment. In essence this is encouraging participation in ‘real time’ and links to the notion of developing effective co-design platforms to achieve this. Situated engagement technologies (e.g., customer feedback kiosks) offer significant potential, as developments in the co-design research process are inherently tied to technological, organizational and societal developments [13]. Within healthcare, these not only complement the existing use co-design approaches but may shed new light on complex issues, e.g., service delivery and the physical environment by drawing upon users in the ‘here and now’ of the space.

We propose that ‘situated’ crowdsourcing[14] – outsourcing a function normally carried out by particular employees to an undefined group of people via an open call [14] – may be used as a tool for this. Thus, the use of situated devices may help user-centered participation for healthcare environment design. The co-design process provides a context in which participants can articulate their values in relation to experiences, in order to generate design ideas, particularly in contexts where design possibilities or problems are poorly understood [12] such as healthcare environments. For this reason, the co-design process places emphasis on the generation of insights based on tacit knowledge through dialogues between participants, designers and researchers. By mediating this dialogue through situated engagement, a new method or tool for the design process may be developed.

### 3. Implementation

In order to scaffold co-design and crowdsourcing via situated engagement we propose an innovative *digital crowdsourcing co-design* approach. This approach aims to provide robust, decentralized and human-scale resources to the co-design process. To examine this approach, we have implemented a *digital crowdsourcing in co-design* prototype. Here we define the prototype as use of a **simulated hospital ward** (to be described in section 3.1) and also use of the **appraisal-collecting kiosk** (to be described in section 3.2). This section presents the implementation of the prototype.

#### 3.1. Simulated Hospital Ward

The simulated hospital ward was implemented using the 3D sound room laboratory (Fig. 1, on the left), at the University of Warwick, in order to provide a crowdsourcing co-design context that could potentially promote situated engagement. The laboratory consists of a 16-speaker system plus a subwoofer together and 3 projector displays. The simulation was produced using previously obtained sound recordings and images (Fig. 1, on the right) from a cardiothoracic (CT) hospital environment. This setting was chosen in order to control (remove) variables such as time pressures, job duties and other context elements that may conflict with the formal appraisal of the *digital crowdsourcing co-design* prototype.

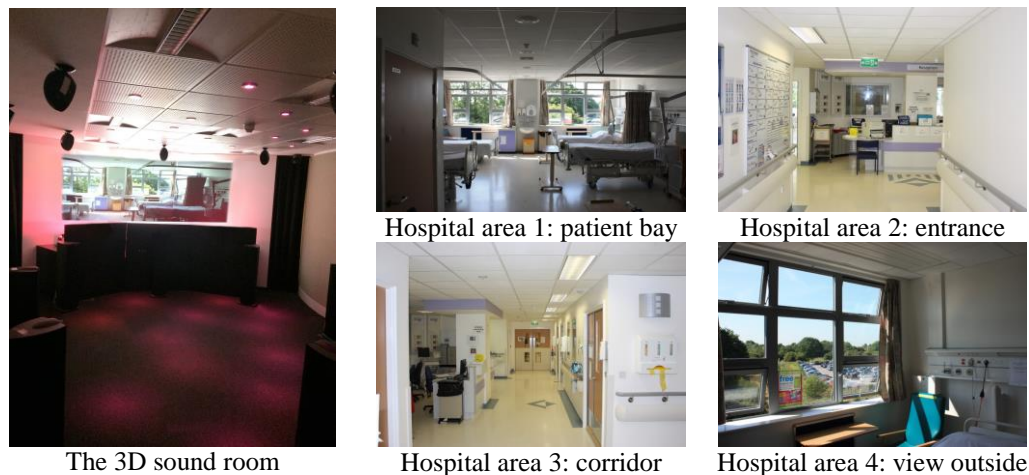


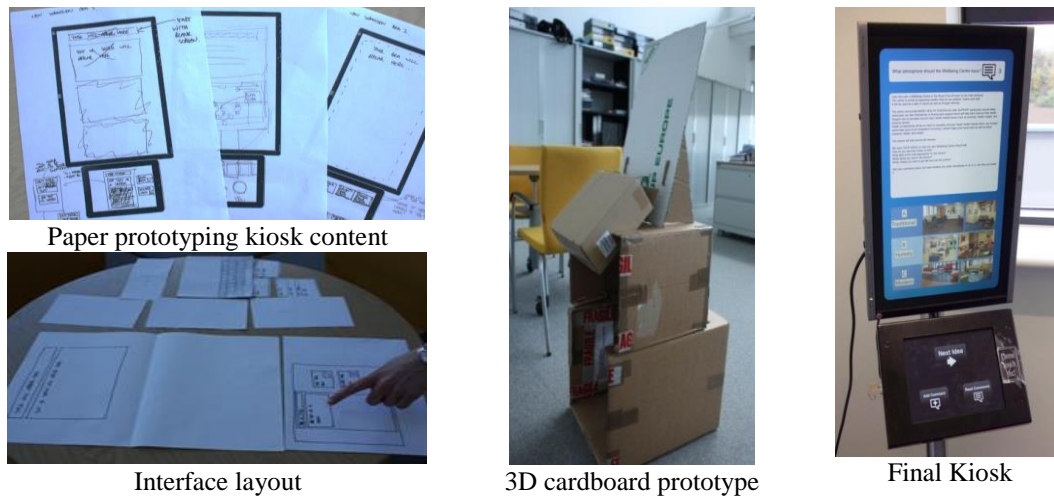
Fig. 1. The 3D sound room (on the left) and the 4 hospital areas to be improved (on the right).

#### 3.2. Appraisal-Collecting Kiosk

The appraisal-collecting kiosk, referred to as the kiosk (Fig. 2), was implemented underpinning the following 4 key components: 1) distributed co-design [33] – participants are separated geographically or by time in the co-design process; 2) information probes [5] – small insights into the everyday concerns of participants are captured; 3) open innovation [18] – an open call for ideas about an area is presented with the sample demographic particular to an area of healthcare; and 4) situated crowdsourcing [15] – participants contribute to co-design while situated within the environment.

The kiosk was implemented using initial sketch and paper prototyping (Fig. 2, on the top left) within the research team to explore and define what information the kiosk would be required to show. Different screen layouts (Fig. 2, in the bottom left) were tried to accommodate the wish for images and text to play roles in producing and mediating tasks for users to complete. 3D cardboard prototypes (Fig. 2, center) were created to ensure that the physical design of the kiosk was able to cater for a variety of user demographics. This allowed modifications to be made and the final dimensions were decided on. The final kiosk (Fig. 2, on the right) consisted of a touchscreen attached to a stand. The touchscreen was fixed

at a height suitable for use while sitting. A monitor was positioned above the touchscreen and displayed questions, text and images.



**Fig. 2.** Kiosk development.

## 4. Evaluation

### 4.1. Settings

The evaluation was conducted at the University of Warwick. 30 participants took part in the experiment. 19 (63.3%) were male and 11 (36.7%) were female. 15 (50%) were computer science PhD students, reporting being familiar with technologies; the remaining 14 (46.7%) were engineering staff and students with 1 (3.3%) math PhD student. Their ages ranged from 24 to 41 (mean 29.9, s.d. 4.17). 9 (30%) were Chinese, 5 (16.7%) were British, with the remaining 16 (53.3%) from 9 other countries.

The participants were asked to sit in the 3D sound room and use the kiosk (Fig. 3, on the left) to improve four simulated cardiothoracic (CT) hospital ward areas, including the patient bay area, the ward corridor, the view outside the ward and the entrance to the ward (Fig. 1, on the right). The first screen that a participant could see was the dashboard (Fig. 3, center image), where the participant could choose which area of the CT hospital ward to improve. Then, the participant could choose to either comment on or draw on the image of the area (Fig. 3, on the right). Thereafter, the participant could go back to the previous screen(s) to choose another task (i.e., commenting on or drawing on the area image) or another area to improve. Note that there was no way to identify which suggestions were submitted by which participants.



**Fig. 3.** The experimental environment and the kiosk.



## 4.2. Questionnaire Survey Design

After submitting suggestions using the kiosk, the participants were asked to fill in a questionnaire survey. The remainder of this sub-section articulates how the questionnaire was designed.

The ultimate success of a technology for healthcare environment co-design is dependent on various factors. User acceptance of the technology is considered as one of the key factors. The Technology Acceptance Model (TAM) provides a valid and reliable measure that predicts user acceptance of technologies [6]. According to TAM (Fig. 4), user acceptance of technologies can be explained mainly by 3 factors including *perceived usefulness*, *perceived ease of use* and *attitude toward using* [7]. *Attitude toward using* is a major determinant of users' decision about whether they will use or reject the technology. *Attitude toward using* can be influenced by the other 2 factors, i.e., *perceived usefulness* and *perceived ease of use*, whilst *perceived ease of use* has a direct influence on *perceived usefulness*.

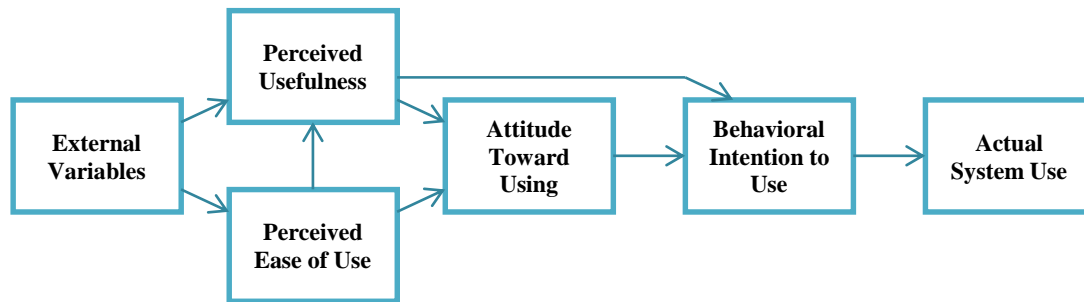


Fig. 4. The Technology Acceptance Model [6].

The TAM has been continuously adapted and expanded such as its adaptation to the healthcare settings [14], e-commerce settings [30] and e-learning settings [28]. One of most important expedition is TAM 2, in which additional variables are added as antecedents to the perceived usefulness variable, as the original TAM has some limitations in explaining the reasons for which a person would perceive a given system useful [30]. However, the original TAM is parsimonious and includes *perceived usefulness* that has consistently explained more variance in technology acceptance than other variables [22]. It also contributes to explaining the association between *perceived usefulness* and the important technology design variable of *perceived ease of use*. Therefore, the study presented in this paper adopted the original TAM, whilst adapting it to assess the evaluation of the *digital crowdsourcing co-design* prototype.

The TAM proposes 3 factors to examine including *perceived usefulness* (PU), *perceived ease of use* (PE) and *attitude toward using*. Eight statements were developed to examine the *perceived usefulness* and *perceived ease of use*, as listed below:

### *Perceived Usefulness (PU)*

- PU.1. The tool helped me to understand how to co-design the hospital ward.
- PU.2. The tool engaged me to participate in co-designing the hospital ward.
- PU.3. The tool inspired me to design the hospital ward.
- PU.4. The tool assisted me to express and record my ideas.

### *Perceived Ease of Use (PE)*

- PE.1. The tool was user-friendly.
- PE.2. The tool required the fewest steps possible to accomplish what I wanted to do.
- PE.3. It was easy to learn how to use the tool.
- PE.4. It was easy to remember how to use the tool.

*Attitude toward using* the tool was measured through statements divided into two categories: *satisfaction of use* (SU) and *confidence of use* (CU), as listed below:

**Satisfaction of Use (SU)**

**SU.1.** The tool was attractive to use.

**SU.2.** The tool was fun to use.

**SU.3.** The tool was pleasant to use.

**Confidence of Use (CU)**

**CU.1.** I felt confident to interact with the tool.

**CU.2.** I felt confident to contribute to the design.

**CU.3.** I felt confident that my contributions were recorded.

Three statements were designed to test the *behavioral intention (BI)*, as listed bellow:

**Behavioral Intention (BI)**

**BI.1.** I would use the tool again for the design.

**BI.2.** I would use the tool frequently for the design.

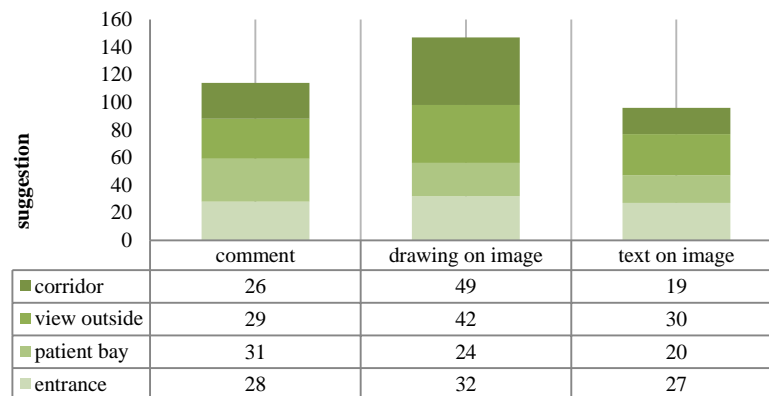
**BI.3.** I would tell other people about the tool.

All the 17 statements were included in the questionnaire. Participants were asked to assign a rating of -2 to 2 on a 5-point Likert scale for each statement, with a rating of -2 meaning that the participant strongly disagreed with the statement, and a rating of 2 meaning that the participant strongly agreed with the statement. Ratings between these two extremes, -2 and 2, represented varying degrees of agreement. Additionally, there was an open question asking for comments on how to improve the implemented *digital crowdsourcing co-design* prototype.

## 5. Results

### 5.1. Co-Design Results

In total, the 30 participants submitted 380 suggestions across the 4 hospital ward areas (mean 12.67, s.d. 5.35, min 25, max 30 per ward area). These suggestions include 102 for the ward corridor, 104 for the view outside the ward, 70 for the patient bay and 104 for the entrance to the ward. In total, they submitted 128 suggestions in the form of comments (mean 28.5, s.d. 2.1, min 26, max 31 per ward area), including 26 comments for corridor improvement, 29 for view outside, 31 for patient bay, and 28 for entrance. In total, they suggested 147 improvements in the form of drawing on the hospital area images (mean 36.8, s.d. 11.0, min 24, max 49 per ward area), including 49 for corridor, 42 for view outside, 24 for patient bay and 32 for entrance. In total they suggested 96 improvements in the form of written text on the hospital area images (mean 24.0, s.d. 5.35, min 19, max 30 per ward area), including 19 for corridor, 30 for view outside, 20 for patient bay and 27 for entrance.



**Fig. 5.** Suggestions submitted by participants



## 5.2. Questionnaire Results

Fig. 6 presents the distribution of responses of the questionnaire survey statements, including both mean and median values of *perceived usefulness* (PU), *perceived ease of use* (PE), *attitude toward using the method* (including *satisfaction of use* (SU) and *confidence of use* (CU)) and *behavioral intention* (BI). Table 1 shows more details of the statistical results including mean values, standard deviations (s.d.) and median values.

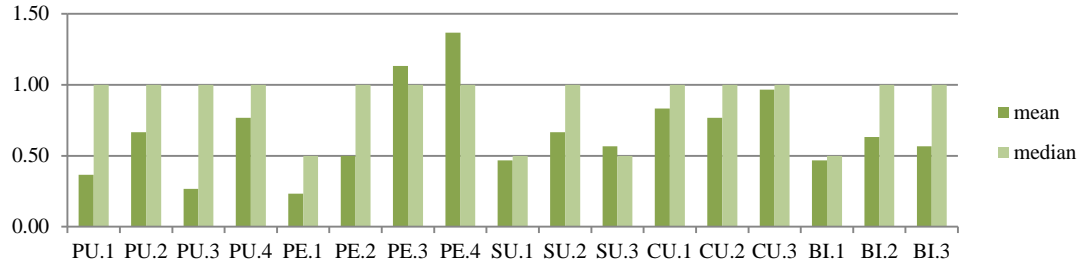


Fig. 6. The questionnaire results

Table 1. The statistical results (n=30)

	mean	s.d.	median		mean	s.d.	median
PU.1	0.37	1.07	1	SU.1	0.47	1.25	0.5
PU.2	0.67	0.92	1	SU.2	0.67	1.15	1
PU.3	0.27	1.01	1	SU.3	0.57	0.97	0.5
PU.4	0.77	1.04	1	CU.1	0.83	0.91	1
PE.1	0.23	1.36	0.5	CU.2	0.77	0.68	1
PE.2	0.50	1.11	1	CU.3	0.97	0.89	1
PE.3	1.13	0.90	1	BI.1	0.47	1.04	0.5
PE.4	1.37	0.72	1	BI.2	0.63	0.85	1
				BI.3	0.57	0.97	1

For *perceived usefulness* (PU), the mean values of the summative results rank between 0.27 and 0.77; their standard deviations (s.d.) are between 0.92 and 1.07; and median are all 1. 53.3% (16 out of 30) of the participants agreed or strongly agreed statement PU.1 “the method helps me to understand how to co-design the healthcare center”. 73.3% (22 out of 30) of the participants agreed or strongly agreed statement PU.2 “the method engages me to participate in the healthcare center co-design”. 53.3% (16 out of 30) of the participants agreed or strongly agreed statement PU.3 “the method inspires me to design the healthcare center”. 66.7% (20 out of 30) of the participants agreed or strongly agreed statement PU.4 “the method assists me to express and record my ideas”.

For *perceived ease of use* (PE), the means of the overall results rank between 0.23 and 1.37; their standard deviations (s.d.) are between 0.72 and 1.36; the medians range between 0.5 and 1. 50.0% (15 out of 30) of the participants agreed or strongly agreed statement PE.1 “the method is user-friendly”. 63.3% (19 out of 30) of the participants agreed or strongly agreed statement PE.2 “the method requires the fewest steps possible to accomplish what I want to do”. 80% (24 out of 30) of the participants agreed or strongly agreed statement PE.3 “it is easy to learn how to use the method”. 93.3% (28 out of 30) of the participants agreed or strongly agreed statement PE.4 “it is easy to remember how to use the method”.

For *attitude toward using the method* including *satisfaction of use* (SU) and *confidence of use* (CU), the means of the overall results rank between 0.47 and 0.97; their standard deviations (s.d.) are between 0.68 and 1.25; and the medians range between 0.5 and 1. 50% (15 out of 30) of the participants agreed or strongly agreed statement SU.1 “the method is attractive to use”. 56.7% (17 out of 30) of the participants agreed or strongly agreed statement SU.2 “the method is fun to use”. 50.0% (15 out of 30) of the participants agreed or strongly agreed statement SU.3 “the method is pleasant to use”. 70% (21 out of 30) of the participants agreed or strongly agreed statement CU.1 “I feel confident to interact with the method”. 70%

(21 out of 30) of the participants agreed or strongly agreed statement **CU.2** “I feel confident to contribute to the design”. 80% (24 out of 30) of the participants agreed or strongly agreed statement **CU.3** “I feel confident that my contributions are recorded”.

For *behavioral intention* (**BI**), the means range between 0.47 and 0.57; their standard deviations (s.d.) are between 0.85 and 1.04; and the medians range between 0.5 and 1. 50.0% (15 out of 30) of the participants agreed or strongly agreed statement **BI.1** “I would use the method again for the design”. 56.7% (17 out of 30) of the participants agreed or strongly agreed statement **BI.2** “I would use the method frequently for the design”. 56.7% (17 out of 30) of the participants agreed or strongly agreed statement **BI.3** “I would tell other people about the method”.

A *Cronbach's Alphas* between 0.7 and 0.9 are considered as highly reliable [4]. As shown in Table 2, all the values for each category of the statements are larger than 0.7 (‘good’ according to [11]), suggesting a high level of reliability of the results.

**Table 2.** Cronbach's Alpha (Reliability Statistics)

	<b>Perceived usefulness</b>	<b>Perceived ease of use</b>	<b>Attitude toward using the method</b>	<b>Behavioral intention</b>
Cronbach's Alpha	0.771	0.721	0.835	0.866
Number of items	4	4	6	3

Additionally, 18 out of 30 participants (60%) answered the open question asking for comments on how to improve the implemented *digital crowdsourcing co-design* prototype. These qualitative responses are generally consistent with the quantitative results from the questionnaire survey, i.e., positive perception of the acceptance of using the prototype. A number of participants expressed interest in using the prototype in the future for the healthcare co-design. They also provided some specific suggestions on further improvement of the method and the prototype. For example, one participant commented: “*add zoom functionality, make the app responsive to finger touch*”. Due to the space limitation, in this paper, we focus on analyzing the above-reported results from the 17 questionnaire statements using descriptive statistics. However, these qualitative responses, along with participants’ direct oral feedback after using the prototype, will be discussed (in section 6) in order to contextualize these descriptive statistics where appropriate.

## 6. Discussion

This section discusses the questionnaire results reported in section 5.2. In general, Table 1 shows that all the mean and median values are greater than 0 (the neutral response), suggesting participants’ perceived acceptance of using the prototype to be positive. In this section, we focus on those highest and lowest rated statements.

### 6.1. Improvement of the Prototype

As shown in Table 1, **PE.3** “it was easy to learn how to use the tool” and **PE.4** “it was easy to remember how to use the tool” are the top 2 rated statements, whilst statement **PE.1** “the tool was user-friendly” received the lowest (still positive, i.e., >0) score, among all the 17 statement. These 3 statements are all related to *perceived ease of use* (**PE**) yet reflect different perspectives. On the one hand, the prototype was perceived easy to learn and remember how to use. On the other hand, the prototype was perceived not user-friendly enough. This indicates the importance of the usability aspect of implementing a digital co-design tool. Participants verbalized these issues as the touchscreen was seen as slow and hospital images should be bigger and clearer. Therefore, in the future, we will improve these features, as well as conduct a usability study to further identify other potential issues to solve.

Table 1 also shows that the category of *Confidence of Use* (consists of **CU.1** “I felt confident to interact with the tool”, **CU.2** “I felt confident to contribute to the design” and

**CU.3** “I felt confident that my contributions were recorded”) received generally higher scores than other categories. This suggests that the implementation met the requirement from crowdsourcing theory that participants are not being judged or scrutinized thus would like to take part. Based on the notion of ‘*Confidence of Use*’ it is possible to suggest that participants may feel more willing to engage in this technology in a repeated manner and so the opportunity to gather a large amount of data in the co-design process exists. Indeed, ‘*Behavioural Intention*’ goes some way to support this. Although mean values are close to the neutral point, the trend indicates an intention to continue to interact with kiosk, again suggesting this (and similar technology) as an asset to co-design. Future work may look to understand how to optimize this aspect of the technology.

Additionally, from Table 1, **PU.1** “the method helped me to understand how to co-design the healthcare center” and **PU.2** “the method inspired me to design the healthcare center” were rated among the lowest. Qualitative feedback also contained similar concerns such as “*a scenario may have aided the questions have more contextual meaning - why do we need to change or improve the design of the ward, for who, and with what considerations?*” This concern may have been due to the simulated hospital environment, as the simulation may not have created a full sense of immersion and so additional context was needed. However, this does raise an interesting point of how to create an immersive simulated healthcare environment as a way not only to improve design, but also aid the development of co-design methods. This will be further discussed in section 6.2.

## 6.2. Limitation and Future Study

The study presented in this paper was conducted in a simulated context, i.e., the visual and aural simulation of a CT hospital ward. In the future we will explore the use of the *digital crowdsourcing co-design* prototype in-situ. Insights and suggestions from this study will allow modification to be made and further in-situ studies to refine its development be carried out. Moreover, this study focused on exploring only hospital staff acceptance of using the method. In the future we will explore the acceptance from healthcare stakeholders’ perspective such as patients and patients’ family; we will also further divide the hospital staff stakeholder category into finer-grained roles such as doctors, nurses, cleaners and administrators. We suspect that different roles may perceive the digital method differently; they may have difference expectations from the method and difference ways of using the method. The further study will contribute to the personalization of the *digital crowdsourcing co-design tool*, thus improving the effectiveness and efficiency of the crowdsourcing co-design process. Although a low number of participants took part in the study, reliability of the responses *Cronbach’s Alpha* suggested a high level of reliability. However, we will conduct future experiments in the context of real-world healthcare environment, expecting to engage more participants to take part in the study, which will also increase the number of participants.

## 7. Conclusion

In this paper, we have reported a preliminary exploration of the co-design approach and crowdsourcing techniques for improving healthcare environments. In particular, we have presented a *digital crowdsourcing co-design* prototype, including its implementation and evaluation, in order to learn how to best deploy such digital tools that can potentially engage and motivate hospital staff to take part in the improvement of their own working space. The implementation focused on the experiment setting-ups including the visual and aural simulation to a cardiothoracic (CT) hospital ward environment, as well as the hardware and software of an appraisal-collecting kiosk. The evaluation focused on investigating if and to what extent participants accepted using the implemented prototype.

The evaluation results showed participants’ positive perception of the acceptance of using the prototype, which indicated that our *digital crowdsourcing co-design* method is promising. We also received participants’ suggestions of the improvement of the prototype, which helped

with evaluating the implemented prototype (including use of simulated environments and the appraisal-collecting tool) and planning further improvements, iterations and studies. By understanding these nuances of interaction with new crowdsourcing co-design approaches we hope to be able to develop innovative ways for user participation in healthcare to help shape the future by user involvement.

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## Digital Crowdsourcing in Healthcare Environment Co-design

**Lei Shi**

*lei.shi@warwick.ac.uk*

*International Digital Laboratory, WMG, University of Warwick  
Coventry, United Kingdom*

**James MacKrill**

*j.b.mackrill@warwick.ac.uk*

*International Digital Laboratory, WMG, University of Warwick  
Coventry, United Kingdom*

**Carolyn Dawson**

*c.h.dawson@warwick.ac.uk*

*International Digital Laboratory, WMG, University of Warwick  
Coventry, United Kingdom*

**Elisavet Dimitrokali**

*e.dimitrokali@warwick.ac.uk*

*International Digital Laboratory, WMG, University of Warwick  
Coventry, United Kingdom*

**Rebecca Cain**

*r.cain.1@warwick.ac.uk*

*International Digital Laboratory, WMG, University of Warwick  
Coventry, United Kingdom*

### Abstract

Improving user experiences of healthcare environments via their participation has become a central theme in healthcare studies and strategic agendas. The co-design approach is often utilized to take into account opinions from different stakeholders including hospital staff. However, there are a number of competing stimuli and demands on staff at any point in time potentially making it difficult for them to participate in the co-design processes. Digital crowdsourcing may engage staff in participating in the design and appraisal of hospital environments when they have a spare moment by collecting small amounts of relevant data. In order to explore this, we have implemented a *digital crowdsourcing co-design* prototype. As users' perceived acceptance of technologies is among the determining factors for a successful digital approach, in this paper, we report on participants' acceptance of the prototype, aiming to reflect if and to what extent they accept this prototype to aid further development.

**Keywords:** Healthcare environment, co-design, crowdsourcing, evaluation, acceptance.

### 1. Introduction

The application of co-design [19] has been adopted by a diverse range of sectors ranging from traditional product development through to application in healthcare. Central to its applications is to understand the user perspective. Improving patient and staff members experiences of healthcare environments and services via their participation has become a central theme in health research [2] and strategic agendas [36]. This has involved different stakeholder groups in discussions about personal experiences of healthcare and how environments and services might be improved, often utilizing the co-design approach. For example, The Kings Fund [37] carried out the Patient Centered Care Project to improve the experience of breast and lung cancer treatment within a UK NHS (National Health Service) hospital. The investigation used "Experience-Based Co-Design" and included interviews, ethnographic observations, and group work.



The participation of different stakeholder groups offers particular contributions to quality improvement thinking in the healthcare sector: a new lens, or frame of mind, through which to think about approaches to improving user experience of healthcare, as well as methods, technologies and tools [10]. Yet, it also raises challenges: how do stakeholders challenge and augment the “finished design” to suggest design changes; how can their subjective opinions, ideas, thoughts, needs and experience about an environment be captured and translated into a format meaningful for designers and engineers?

Crowdsourcing [16] is the process of obtaining needed ideas, solutions or content by soliciting contributions from a large group of people. It takes the crowd’s contribution as a whole, which can potentially eliminate bias and omit missing data thus reducing risks. The emergence of crowdsourcing may fundamentally change the co-design approach as designers can now play with these “new materials” and the way of obtaining them. This introduces a new context for crowdsourcing where researchers and designers may tackle the co-design challenges in the healthcare sector.

The work presented in this paper investigates the application and use of the co-design approach and crowdsourcing technology, in order to promote situated engagement of hospital staff in the appraisal and improvement of healthcare environments. This work follows a *research through design* approach [34] where speculative prototypes are developed using methods from Human-Computer Interaction (HCI) and from environment and service design, as a way of learning how to best deploy such digital co-design tools.

This paper presents a preliminary study on the implementation and evaluation of a *digital crowdsourcing co-design* prototype. Given the fact that participants’ acceptance of taking part in the co-design process using digital co-design tools can potentially influence the quality and quantity of their participation and contribution, their acceptance of the method is among the determining factors for the success [31]. Therefore, it is crucial to investigate if and to what extent they accept the proposed method. The results may in turn reveal the influence of the acceptance, thus suggesting further development and improvement of the method. This study was designed to understand the use of the method in a controlled environment. Therefore, this paper focuses exclusively on examining participants’ perceived acceptance of the implemented prototype, in the context of hospital ward simulated within a controlled environment. Acceptance was then assessed using a questionnaire survey designed based on a previous study [21] that applied the Technology Acceptance Model (TAM) [6].

## 2. Related Work

### 2.1. Co-Design

Co-design is an iterative, interactive and inclusive process where all stakeholders including researchers, designers and people formerly known as the “users” are engaged in the development of new solutions [19]. It encourages the blurring of the role between different stakeholders, focusing on the process by which design objectives are achieved. It believes that the final results will be more appropriate and acceptable to end-users by encouraging this co-creation of solutions, as the quality of design increases if the stakeholders’ interests are considered in the design process [1]. Over the past decades co-design has been widely accepted in the areas of product design, system design, service design, and human-computer interaction (HCI) [17]. A more recent study [20] theorized that this creativity-based approach requires scaffolding of the physical design space a team works in, the space constituted by participant activities, and the future solutions being developed. This normally involves methods such as workshop-based design sessions that need participants’ time commitment.

However, in the context of healthcare environment improvement where staff members have multiple demands at any point in time, there are many challenges to bring them in the co-design process using traditional workshop-based methods. Thus, the study presented in this paper aims to explore an innovative method drawing from the recent attempts to adapt the

co-design approach through situated participation [33] and using social computing techniques to engage users who may be dispersed due to work activities (e.g., [9, 32]).

## 2.2. Crowdsourcing

Crowdsourcing can be seen as a particular distributed co-creation model that provides a comfortable venue where participants are not being judged or scrutinized thus might feel more comfortable to participate. It can be very efficient and effective as participants are less conscious or aware of scrutiny towards their contribution [8]. It can be seen as a form of “open innovation”, which depends heavily on the involvement and engagement of participants [18]; it can also be seen as information probes [5] capturing small insights into the everyday concerns of participants. The offerings of crowdsourcing, its desires and aims are in a way overlapped with those of co-design, by eliciting insights from users. Therefore, linking the two approaches may provide robust, decentralized and human-scale resources to the co-design process. Thus crowdsourcing models can potentially bring in benefits to co-design, especially in the context of improving healthcare environments. However, it is difficult to prototype crowdsourcing platforms, as researchers and engineers are not able to precisely predict if and to what extent users will contribute the information required to make a platform valuable to them [35].

Whilst little research has been done on how to design and improve prototyping of crowdsourcing platforms, a great amount of studies have been conducted to investigate theories and practices capable of engaging and motivating participants’ contribution. Take the field of social computing for example, extensive work has been done to explore specific approaches to increase interaction, collaboration, and cooperation among individuals, as well as contribution to a community. These approaches include tightening social connection [27], visualizing social interaction [23], exposing individual performance and contribution [24], adopting gamification strategies [26], and applying motivational theories [25] such as social connectivism [29] and self-determination theory (SDT) [3]. These overarching studies can potentially contribute to the development of co-design crowdsourcing platforms. Therefore, the study presented in this paper takes into consideration these theories and practices when implementing and evaluating the prototype.

## 2.3. Situated Engagement

Situated engagement is the process of engaging an individual at a moment of time within a specific environment. In essence this is encouraging participation in ‘real time’ and links to the notion of developing effective co-design platforms to achieve this. Situated engagement technologies (e.g., customer feedback kiosks) offer significant potential, as developments in the co-design research process are inherently tied to technological, organizational and societal developments [13]. Within healthcare, these not only complement the existing use co-design approaches but may shed new light on complex issues, e.g., service delivery and the physical environment by drawing upon users in the ‘here and now’ of the space.

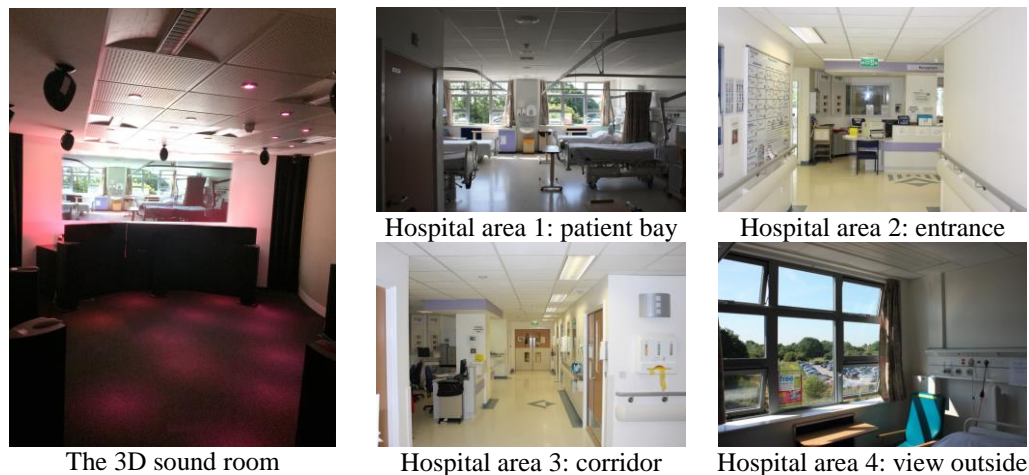
We propose that ‘situated’ crowdsourcing[14] – outsourcing a function normally carried out by particular employees to an undefined group of people via an open call [14] – may be used as a tool for this. Thus, the use of situated devices may help user-centered participation for healthcare environment design. The co-design process provides a context in which participants can articulate their values in relation to experiences, in order to generate design ideas, particularly in contexts where design possibilities or problems are poorly understood [12] such as healthcare environments. For this reason, the co-design process places emphasis on the generation of insights based on tacit knowledge through dialogues between participants, designers and researchers. By mediating this dialogue through situated engagement, a new method or tool for the design process may be developed.

### 3. Implementation

In order to scaffold co-design and crowdsourcing via situated engagement we propose an innovative *digital crowdsourcing co-design* approach. This approach aims to provide robust, decentralized and human-scale resources to the co-design process. To examine this approach, we have implemented a *digital crowdsourcing in co-design* prototype. Here we define the prototype as use of a **simulated hospital ward** (to be described in section 3.1) and also use of the **appraisal-collecting kiosk** (to be described in section 3.2). This section presents the implementation of the prototype.

#### 3.1. Simulated Hospital Ward

The simulated hospital ward was implemented using the 3D sound room laboratory (Fig. 1, on the left), at the University of Warwick, in order to provide a crowdsourcing co-design context that could potentially promote situated engagement. The laboratory consists of a 16-speaker system plus a subwoofer together and 3 projector displays. The simulation was produced using previously obtained sound recordings and images (Fig. 1, on the right) from a cardiothoracic (CT) hospital environment. This setting was chosen in order to control (remove) variables such as time pressures, job duties and other context elements that may conflict with the formal appraisal of the *digital crowdsourcing co-design* prototype.



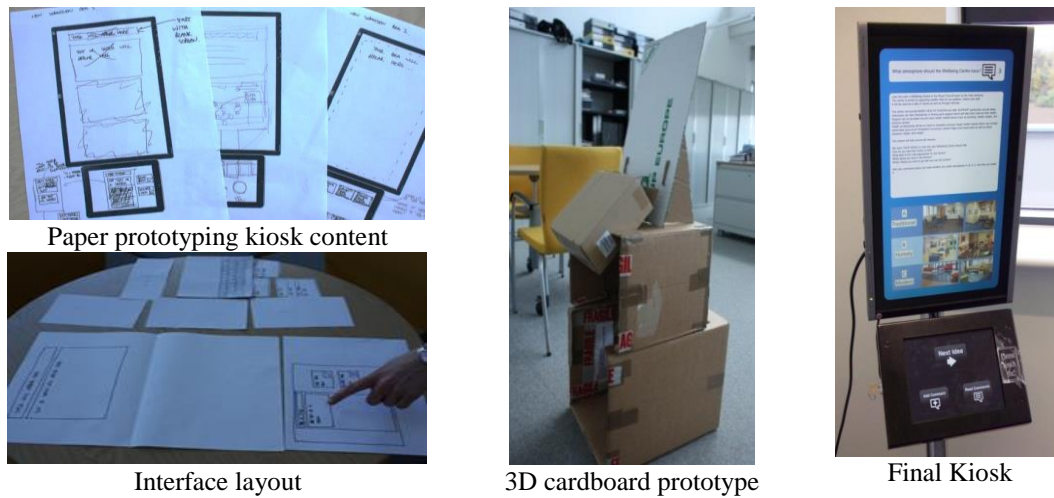
**Fig. 1.** The 3D sound room (on the left) and the 4 hospital areas to be improved (on the right).

#### 3.2. Appraisal-Collecting Kiosk

The appraisal-collecting kiosk, referred to as the kiosk (Fig. 2), was implemented underpinning the following 4 key components: 1) distributed co-design [33] – participants are separated geographically or by time in the co-design process; 2) information probes [5] – small insights into the everyday concerns of participants are captured; 3) open innovation [18] – an open call for ideas about an area is presented with the sample demographic particular to an area of healthcare; and 4) situated crowdsourcing [15] – participants contribute to co-design while situated within the environment.

The kiosk was implemented using initial sketch and paper prototyping (Fig. 2, on the top left) within the research team to explore and define what information the kiosk would be required to show. Different screen layouts (Fig. 2, in the bottom left) were tried to accommodate the wish for images and text to play roles in producing and mediating tasks for users to complete. 3D cardboard prototypes (Fig. 2, center) were created to ensure that the physical design of the kiosk was able to cater for a variety of user demographics. This allowed modifications to be made and the final dimensions were decided on. The final kiosk (Fig. 2, on the right) consisted of a touchscreen attached to a stand. The touchscreen was fixed

at a height suitable for use while sitting. A monitor was positioned above the touchscreen and displayed questions, text and images.



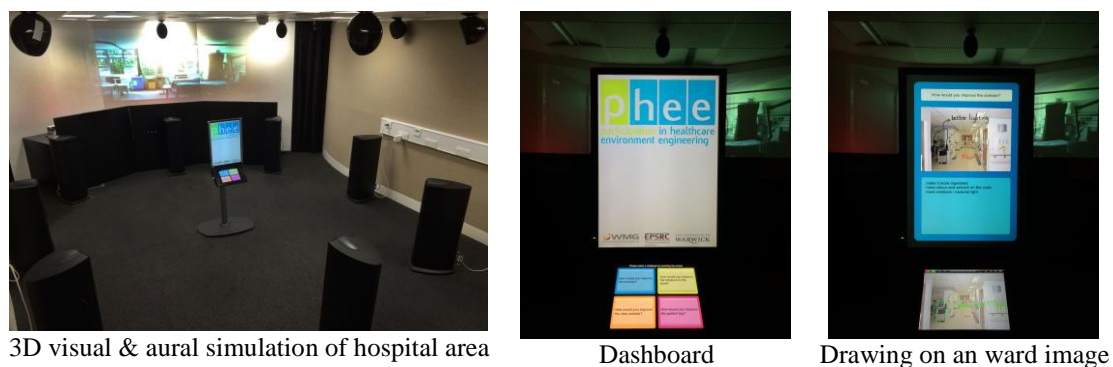
**Fig. 2.** Kiosk development.

## 4. Evaluation

### 4.1. Settings

The evaluation was conducted at the University of Warwick. 30 participants took part in the experiment. 19 (63.3%) were male and 11 (36.7%) were female. 15 (50%) were computer science PhD students, reporting being familiar with technologies; the remaining 14 (46.7%) were engineering staff and students with 1 (3.3%) math PhD student. Their ages ranged from 24 to 41 (mean 29.9, s.d. 4.17). 9 (30%) were Chinese, 5 (16.7%) were British, with the remaining 16 (53.3%) from 9 other countries.

The participants were asked to sit in the 3D sound room and use the kiosk (Fig. 3, on the left) to improve four simulated cardiothoracic (CT) hospital ward areas, including the patient bay area, the ward corridor, the view outside the ward and the entrance to the ward (Fig. 1, on the right). The first screen that a participant could see was the dashboard (Fig. 3, center image), where the participant could choose which area of the CT hospital ward to improve. Then, the participant could choose to either comment on or draw on the image of the area (Fig. 3, on the right). Thereafter, the participant could go back to the previous screen(s) to choose another task (i.e., commenting on or drawing on the area image) or another area to improve. Note that there was no way to identify which suggestions were submitted by which participants.



**Fig. 3.** The experimental environment and the kiosk.

## 4.2. Questionnaire Survey Design

After submitting suggestions using the kiosk, the participants were asked to fill in a questionnaire survey. The remainder of this sub-section articulates how the questionnaire was designed.

The ultimate success of a technology for healthcare environment co-design is dependent on various factors. User acceptance of the technology is considered as one of the key factors. The Technology Acceptance Model (TAM) provides a valid and reliable measure that predicts user acceptance of technologies [6]. According to TAM (Fig. 4), user acceptance of technologies can be explained mainly by 3 factors including *perceived usefulness*, *perceived ease of use* and *attitude toward using* [7]. *Attitude toward using* is a major determinant of users' decision about whether they will use or reject the technology. *Attitude toward using* can be influenced by the other 2 factors, i.e., *perceived usefulness* and *perceived ease of use*, whilst *perceived ease of use* has a direct influence on *perceived usefulness*.

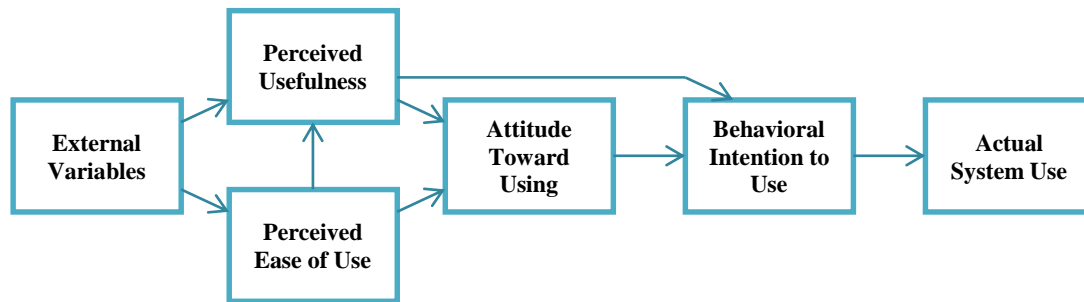


Fig. 4. The Technology Acceptance Model [6].

The TAM has been continuously adapted and expanded such as its adaptation to the healthcare settings [14], e-commerce settings [30] and e-learning settings [28]. One of most important expedition is TAM 2, in which additional variables are added as antecedents to the perceived usefulness variable, as the original TAM has some limitations in explaining the reasons for which a person would perceive a given system useful [30]. However, the original TAM is parsimonious and includes *perceived usefulness* that has consistently explained more variance in technology acceptance than other variables [22]. It also contributes to explaining the association between *perceived usefulness* and the important technology design variable of *perceived ease of use*. Therefore, the study presented in this paper adopted the original TAM, whilst adapting it to assess the evaluation of the *digital crowdsourcing co-design* prototype.

The TAM proposes 3 factors to examine including *perceived usefulness* (PU), *perceived ease of use* (PE) and *attitude toward using*. Eight statements were developed to examine the *perceived usefulness* and *perceived ease of use*, as listed below:

### *Perceived Usefulness (PU)*

- PU.1. The tool helped me to understand how to co-design the hospital ward.
- PU.2. The tool engaged me to participate in co-designing the hospital ward.
- PU.3. The tool inspired me to design the hospital ward.
- PU.4. The tool assisted me to express and record my ideas.

### *Perceived Ease of Use (PE)*

- PE.1. The tool was user-friendly.
- PE.2. The tool required the fewest steps possible to accomplish what I wanted to do.
- PE.3. It was easy to learn how to use the tool.
- PE.4. It was easy to remember how to use the tool.

*Attitude toward using* the tool was measured through statements divided into two categories: *satisfaction of use* (SU) and *confidence of use* (CU), as listed below:

**Satisfaction of Use (SU)**

**SU.1.** The tool was attractive to use.

**SU.2.** The tool was fun to use.

**SU.3.** The tool was pleasant to use.

**Confidence of Use (CU)**

**CU.1.** I felt confident to interact with the tool.

**CU.2.** I felt confident to contribute to the design.

**CU.3.** I felt confident that my contributions were recorded.

Three statements were designed to test the *behavioral intention (BI)*, as listed bellow:

**Behavioral Intention (BI)**

**BI.1.** I would use the tool again for the design.

**BI.2.** I would use the tool frequently for the design.

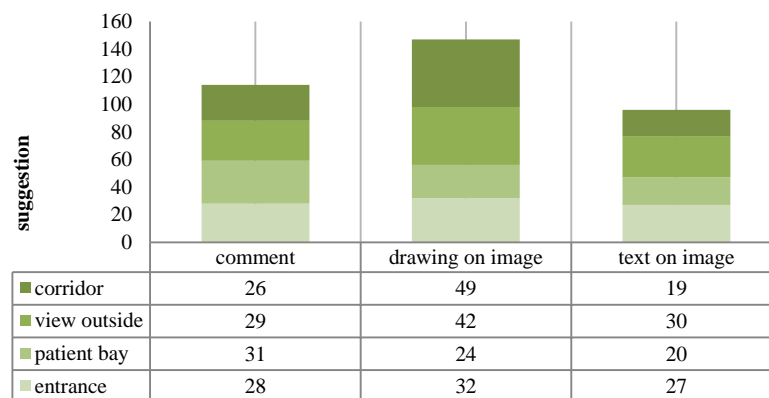
**BI.3.** I would tell other people about the tool.

All the 17 statements were included in the questionnaire. Participants were asked to assign a rating of -2 to 2 on a 5-point Likert scale for each statement, with a rating of -2 meaning that the participant strongly disagreed with the statement, and a rating of 2 meaning that the participant strongly agreed with the statement. Ratings between these two extremes, -2 and 2, represented varying degrees of agreement. Additionally, there was an open question asking for comments on how to improve the implemented *digital crowdsourcing co-design* prototype.

## 5. Results

### 5.1. Co-Design Results

In total, the 30 participants submitted 380 suggestions across the 4 hospital ward areas (mean 12.67, s.d. 5.35, min 25, max 30 per ward area). These suggestions include 102 for the ward corridor, 104 for the view outside the ward, 70 for the patient bay and 104 for the entrance to the ward. In total, they submitted 128 suggestions in the form of comments (mean 28.5, s.d. 2.1, min 26, max 31 per ward area), including 26 comments for corridor improvement, 29 for view outside, 31 for patient bay, and 28 for entrance. In total, they suggested 147 improvements in the form of drawing on the hospital area images (mean 36.8, s.d. 11.0, min 24, max 49 per ward area), including 49 for corridor, 42 for view outside, 24 for patient bay and 32 for entrance. In total they suggested 96 improvements in the form of written text on the hospital area images (mean 24.0, s.d. 5.35, min 19, max 30 per ward area), including 19 for corridor, 30 for view outside, 20 for patient bay and 27 for entrance.



**Fig. 5.** Suggestions submitted by participants



## 5.2. Questionnaire Results

Fig. 6 presents the distribution of responses of the questionnaire survey statements, including both mean and median values of *perceived usefulness* (PU), *perceived ease of use* (PE), *attitude toward using the method* (including *satisfaction of use* (SU) and *confidence of use* (CU)) and *behavioral intention* (BI). Table 1 shows more details of the statistical results including mean values, standard deviations (s.d.) and median values.

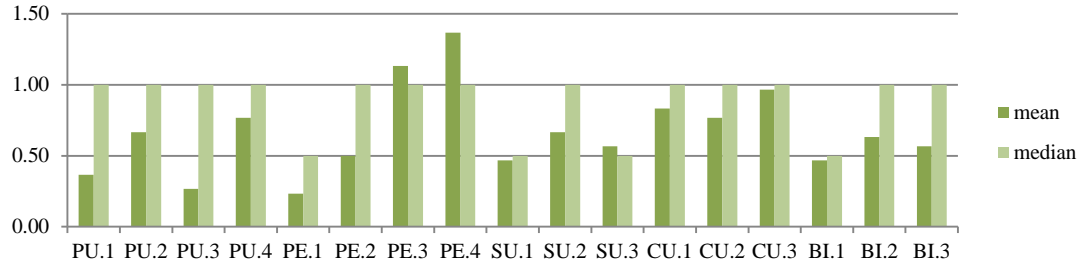


Fig. 6. The questionnaire results

Table 1. The statistical results (n=30)

	mean	s.d.	median		mean	s.d.	median
PU.1	0.37	1.07	1	SU.1	0.47	1.25	0.5
PU.2	0.67	0.92	1	SU.2	0.67	1.15	1
PU.3	0.27	1.01	1	SU.3	0.57	0.97	0.5
PU.4	0.77	1.04	1	CU.1	0.83	0.91	1
PE.1	0.23	1.36	0.5	CU.2	0.77	0.68	1
PE.2	0.50	1.11	1	CU.3	0.97	0.89	1
PE.3	1.13	0.90	1	BI.1	0.47	1.04	0.5
PE.4	1.37	0.72	1	BI.2	0.63	0.85	1
				BI.3	0.57	0.97	1

For *perceived usefulness* (PU), the mean values of the summative results rank between 0.27 and 0.77; their standard deviations (s.d.) are between 0.92 and 1.07; and median are all 1. 53.3% (16 out of 30) of the participants agreed or strongly agreed statement PU.1 “the method helps me to understand how to co-design the healthcare center”. 73.3% (22 out of 30) of the participants agreed or strongly agreed statement PU.2 “the method engages me to participate in the healthcare center co-design”. 53.3% (16 out of 30) of the participants agreed or strongly agreed statement PU.3 “the method inspires me to design the healthcare center”. 66.7% (20 out of 30) of the participants agreed or strongly agreed statement PU.4 “the method assists me to express and record my ideas”.

For *perceived ease of use* (PE), the means of the overall results rank between 0.23 and 1.37; their standard deviations (s.d.) are between 0.72 and 1.36; the medians range between 0.5 and 1. 50.0% (15 out of 30) of the participants agreed or strongly agreed statement PE.1 “the method is user-friendly”. 63.3% (19 out of 30) of the participants agreed or strongly agreed statement PE.2 “the method requires the fewest steps possible to accomplish what I want to do”. 80% (24 out of 30) of the participants agreed or strongly agreed statement PE.3 “it is easy to learn how to use the method”. 93.3% (28 out of 30) of the participants agreed or strongly agreed statement PE.4 “it is easy to remember how to use the method”.

For *attitude toward using the method* including *satisfaction of use* (SU) and *confidence of use* (CU), the means of the overall results rank between 0.47 and 0.97; their standard deviations (s.d.) are between 0.68 and 1.25; and the medians range between 0.5 and 1. 50% (15 out of 30) of the participants agreed or strongly agreed statement SU.1 “the method is attractive to use”. 56.7% (17 out of 30) of the participants agreed or strongly agreed statement SU.2 “the method is fun to use”. 50.0% (15 out of 30) of the participants agreed or strongly agreed statement SU.3 “the method is pleasant to use”. 70% (21 out of 30) of the participants agreed or strongly agreed statement CU.1 “I feel confident to interact with the method”. 70%



(21 out of 30) of the participants agreed or strongly agreed statement **CU.2** “I feel confident to contribute to the design”. 80% (24 out of 30) of the participants agreed or strongly agreed statement **CU.3** “I feel confident that my contributions are recorded”.

For *behavioral intention* (**BI**), the means range between 0.47 and 0.57; their standard deviations (s.d.) are between 0.85 and 1.04; and the medians range between 0.5 and 1. 50.0% (15 out of 30) of the participants agreed or strongly agreed statement **BI.1** “I would use the method again for the design”. 56.7% (17 out of 30) of the participants agreed or strongly agreed statement **BI.2** “I would use the method frequently for the design”. 56.7% (17 out of 30) of the participants agreed or strongly agreed statement **BI.3** “I would tell other people about the method”.

A *Cronbach's Alphas* between 0.7 and 0.9 are considered as highly reliable [4]. As shown in Table 2, all the values for each category of the statements are larger than 0.7 (‘good’ according to [11]), suggesting a high level of reliability of the results.

**Table 2.** Cronbach's Alpha (Reliability Statistics)

	<b>Perceived usefulness</b>	<b>Perceived ease of use</b>	<b>Attitude toward using the method</b>	<b>Behavioral intention</b>
Cronbach's Alpha	0.771	0.721	0.835	0.866
Number of items	4	4	6	3

Additionally, 18 out of 30 participants (60%) answered the open question asking for comments on how to improve the implemented *digital crowdsourcing co-design* prototype. These qualitative responses are generally consistent with the quantitative results from the questionnaire survey, i.e., positive perception of the acceptance of using the prototype. A number of participants expressed interest in using the prototype in the future for the healthcare co-design. They also provided some specific suggestions on further improvement of the method and the prototype. For example, one participant commented: “*add zoom functionality, make the app responsive to finger touch*”. Due to the space limitation, in this paper, we focus on analyzing the above-reported results from the 17 questionnaire statements using descriptive statistics. However, these qualitative responses, along with participants’ direct oral feedback after using the prototype, will be discussed (in section 6) in order to contextualize these descriptive statistics where appropriate.

## 6. Discussion

This section discusses the questionnaire results reported in section 5.2. In general, Table 1 shows that all the mean and median values are greater than 0 (the neutral response), suggesting participants’ perceived acceptance of using the prototype to be positive. In this section, we focus on those highest and lowest rated statements.

### 6.1. Improvement of the Prototype

As shown in Table 1, **PE.3** “it was easy to learn how to use the tool” and **PE.4** “it was easy to remember how to use the tool” are the top 2 rated statements, whilst statement **PE.1** “the tool was user-friendly” received the lowest (still positive, i.e., >0) score, among all the 17 statement. These 3 statements are all related to *perceived ease of use* (**PE**) yet reflect different perspectives. On the one hand, the prototype was perceived easy to learn and remember how to use. On the other hand, the prototype was perceived not user-friendly enough. This indicates the importance of the usability aspect of implementing a digital co-design tool. Participants verbalized these issues as the touchscreen was seen as slow and hospital images should be bigger and clearer. Therefore, in the future, we will improve these features, as well as conduct a usability study to further identify other potential issues to solve.

Table 1 also shows that the category of *Confidence of Use* (consists of **CU.1** “I felt confident to interact with the tool”, **CU.2** “I felt confident to contribute to the design” and

**CU.3** “I felt confident that my contributions were recorded”) received generally higher scores than other categories. This suggests that the implementation met the requirement from crowdsourcing theory that participants are not being judged or scrutinized thus would like to take part. Based on the notion of ‘*Confidence of Use*’ it is possible to suggest that participants may feel more willing to engage in this technology in a repeated manner and so the opportunity to gather a large amount of data in the co-design process exists. Indeed, ‘*Behavioural Intention*’ goes some way to support this. Although mean values are close to the neutral point, the trend indicates an intention to continue to interact with kiosk, again suggesting this (and similar technology) as an asset to co-design. Future work may look to understand how to optimize this aspect of the technology.

Additionally, from Table 1, **PU.1** “the method helped me to understand how to co-design the healthcare center” and **PU.2** “the method inspired me to design the healthcare center” were rated among the lowest. Qualitative feedback also contained similar concerns such as “*a scenario may have aided the questions have more contextual meaning - why do we need to change or improve the design of the ward, for who, and with what considerations?*” This concern may have been due to the simulated hospital environment, as the simulation may not have created a full sense of immersion and so additional context was needed. However, this does raise an interesting point of how to create an immersive simulated healthcare environment as a way not only to improve design, but also aid the development of co-design methods. This will be further discussed in section 6.2.

## 6.2. Limitation and Future Study

The study presented in this paper was conducted in a simulated context, i.e., the visual and aural simulation of a CT hospital ward. In the future we will explore the use of the *digital crowdsourcing co-design* prototype in-situ. Insights and suggestions from this study will allow modification to be made and further in-situ studies to refine its development be carried out. Moreover, this study focused on exploring only hospital staff acceptance of using the method. In the future we will explore the acceptance from healthcare stakeholders’ perspective such as patients and patients’ family; we will also further divide the hospital staff stakeholder category into finer-grained roles such as doctors, nurses, cleaners and administrators. We suspect that different roles may perceive the digital method differently; they may have difference expectations from the method and difference ways of using the method. The further study will contribute to the personalization of the *digital crowdsourcing co-design tool*, thus improving the effectiveness and efficiency of the crowdsourcing co-design process. Although a low number of participants took part in the study, reliability of the responses *Cronbach’s Alpha* suggested a high level of reliability. However, we will conduct future experiments in the context of real-world healthcare environment, expecting to engage more participants to take part in the study, which will also increase the number of participants.

## 7. Conclusion

In this paper, we have reported a preliminary exploration of the co-design approach and crowdsourcing techniques for improving healthcare environments. In particular, we have presented a *digital crowdsourcing co-design* prototype, including its implementation and evaluation, in order to learn how to best deploy such digital tools that can potentially engage and motivate hospital staff to take part in the improvement of their own working space. The implementation focused on the experiment setting-ups including the visual and aural simulation to a cardiothoracic (CT) hospital ward environment, as well as the hardware and software of an appraisal-collecting kiosk. The evaluation focused on investigating if and to what extent participants accepted using the implemented prototype.

The evaluation results showed participants’ positive perception of the acceptance of using the prototype, which indicated that our *digital crowdsourcing co-design* method is promising. We also received participants’ suggestions of the improvement of the prototype, which helped

with evaluating the implemented prototype (including use of simulated environments and the appraisal-collecting tool) and planning further improvements, iterations and studies. By understanding these nuances of interaction with new crowdsourcing co-design approaches we hope to be able to develop innovative ways for user participation in healthcare to help shape the future by user involvement.

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